THE EFFECTS OF STIMULUS CHARACTERISTICS ON THE RELATIONSHIP BETWEEN THE VISUAL EVOKED RESPONSE AND INTELLIGENCE

By
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A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL OF
THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE
OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1974

To my parents who made it all possible.

To David who made it all worthwhile.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Dr. Nathan Perry, Chairman of my supervisory committee, for his counsel and encouragement during this study and throughout my graduate work. I also wish to thank the members of my committee, Dr. Jacquelin Goldman, Dr. Wiley Rasbury, Dr. Calvin Adams, and Dr. Arnold Nevis, for their thoughtful comments and guidance.

Special thanks are due Judy McCoy, Janet Falgout, and Alan Pope for their continued interest and assistance. Finally, I would like to thank Dr. David Spray for his support, encouragement, and understanding.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate Council of
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August, 1974

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Major Department: Psychology

A number of investigators have studied the relationship between the visual evoked response (VER) and intelligence. However, these studies have been characterized by the use of relatively simple stimuli to elicit the response. Electrophysiological research with animals has indicated that neural processing varies with different types of stimuli. This study was designed to assess the effects of different types of stimuli on the VER, and on the relationship between the VER and intelligence. Four stimulus conditions were used: Flash, Checkerboard, Word, and Nonsense syllable. VERs were recorded from positions C_3 and C_4 of the 10-20 International electrode system of 37 boys, ages ten and eleven, whose short form WISC scores ranged from 88-138. The Culture Fair Test was also administered to provide a measure which was relatively free from sociocultural bias. It was thought that this measure would yield higher correlations with VER characteristics.

It was found that the highest and largest number of significant correlations with intelligence occurred under the Flash condition, and the fewest under the Word. The short form WISC yielded the largest number of significant correlations with VER and the Verbal score almost as many; the Culture Fair Test proved to correlate poorly with the VER. The results confirmed the findings of other investigators that the latency of the VER is negatively correlated with intelligence. Amplitude was found to correlate negatively with intelligence in the first three components (IV, Va, Vb), and positively in the last two components (Vc, VI).

The results suggest that ongoing cognitive processes as well as underlying neural organization are reflected in the VER. The relationship of attention and arousal to the correlations between the VER measures and intelligence was discussed in terms of the different stimulus conditions and intelligence tests. It was pointed out that while the latency and amplitude of the VER were found to be significantly correlated with intelligence, variations between individuals were great, and these measures have little practical value at this time in the assessment of intelligence.

INTRODUCTION

Since the times when phrenologists attempted to assess brain power by the bulges of the forehead, science has searched for a relationship between brain and intelligence. It is generally accepted today that neural structure and function underlie cognitive capabilities. However, as recently as 1965, a review of the literature concluded that no broad principles of the neurophysiological correlates of intelligence had yet been established (Ferguson, 1965).

Early work seeking electrophysiological measures of cognitive ability was concerned with EEG frequency, particularly 10-14 Hz or alpha waves. Ellingson (1966) reviewed the area and concluded that the bulk of the evidence suggested no relationship between EEG and intelligence in adults. In children, results were contradictory and confounded by the effect which organic brain dysfunction has on both EEG activity and intelligence. These conclusions were refuted by Vogel and Broverman (1966). Recent studies have found positive correlations between slow waves and general ability (Vogel, Broverman, and Klaiber, 1968) and positive results using factor analytic techniques (Ishihara and Yoshii, 1972). It would seem that no unequivocal statements can be made at present about the relationship between the EEG and intelligence.

In 1965, Chalke and Ertl reported striking correlations, as high as -.70, between IQ scores and the latency of the visual evoked response. The visual evoked response, or VER, is the computer-averaged sum of individual electrical responses elicited by a repetitive photic stimulus. Spontaneous, ongoing cortical activity averages 50 uV, while the response evoked by a single stimulus is less than 10 uV. Therefore, specialized computer techniques are required to extract the small signal, or response, from the larger "noise" of the EEG. Evoked responses are time-locked to a repetitive stimulus, and when summed, they provide a record of the response to that stimulus. The averaged EEG, which is not time-locked, appears as a relatively straight line. Auditory and somatosensory, as well as visual stimuli can be used to generate an evoked response which is recorded on the scalp with surface electrodes. A diffuse light flash is the most commonly used visual stimulus, although patterned light may also be used. The early components of the evoked response are postulated to represent perceptual processing; the later components, information processing (John, Ruchkin, and Villegas, 1964; Uttal and Cook, 1964; Ertl, 1968).

Since Chalke and Ertl's report, a number of investigators have studied the area. It is somewhat difficult to assess the VER-IQ literature, as the studies are not strictly comparable, because of methodological differences. Subject populations studied vary widely, electrode recording sites differ, diverse measures of intellectual performance are used, and different VER characteristics are studied.

A number of studies have been able to replicate Chalke and Ertl's negative correlations of latency and intelligence in bright and dull adults (Plum, 1968; Shucard and Horne, 1972), in children (Ertl, 1968; Ertl and Schaefer, 1969), and with retardates (Bigum, Dustman, and Beck, 1970; Galbraith, Gliddon, and Busk, 1970; Marcus, 1970). In general, correlations were lower than those found by Chalke and Ertl, but statistically significant. Highly significant negative correlations were found between latency of the neonatal VER and mental and motor development at eight months (Butler and Engel, 1969), but there was no latency correlation with language at three years, or with IQ at four years (Engel and Fay, 1972), or at seven years (Henderson and Engel, 1974). Neither was a relationship between VER latency and intelligence found by Rhodes and his co-workers (Rhodes, Dustman, and Beck, 1969).

Other characteristics of the VER have also been found to correlate with intellectual ability. Greater amplitudes of response components have been found in brighter children and adults than in those less bright (Rhodes et al., 1969; Bigum et al., 1970; Galbraith et al., 1970). However, Marcus (1970) reports larger response amplitudes in Mongoloid than in normal infants. Hemispheric asymmetry of VER amplitude has often been noted, but results have been highly inconsistent. Several studies report amplitude asymmetry to be characteristic of normals, but not of dull or retarded children (Rhodes et al., 1969; Bigum at al., 1970, Galbraith et al., 1970). However, another study (Richlin, Weisinger, Weinstein, Gianni, and

Morganstern, 1971) found amplitudes greater in the right hemisphere than in the left in normals, and the reverse, left greater than right, in retarded children. Plum (1968) found no relation between asymmetry and intelligence.

A few investigators have used auditory evoked response (AERs) in studies of intelligence. These studies use clicks, white noise, or pure tones as stimulus, and record from central and temporal areas of the scalp. The amplitude of certain AER components were found to be larger in Mongoloid infants than in normal infants (Barnet and Lodge, 1967; Barnet, 1971). Response decrement, i.e., the progressive decrease in response amplitudes with repetitive stimulation, was seen in normal six to twelve month old infants, but was not seen in Mongoloid infants of the same age (Barnet and Lodge, 1967; Barnet, Ohlrich, and Shanks, 1971). Latency differences were generally not found between normal and retarded, or normal and Mongoloid subjects (Barnet and Lodge, 1967; Barnet, 1971; Barnet et al., 1971; Richlin et al., 1971). The exception is Shimizu (1969) who reports a trend, although not a statistically significant one, toward larger response latencies in retarded subjects. He also found that AER latency and wave shape were reliable in normal adults, but inconsistent in mentally retarded adults.

Despite the diversity of methodologies used in studies of correlations between the VER and intelligence, there is general agreement that low, but statistically significant correlations exist. It seems reasonable to expect a more complex visual stimulus to require more complex neural processing. Just as a more difficult behavioral task is a more precise indicator of intelligence than a simpler one, so a more complex neurological task should yield a more accurate picture of the cognitive efficiency of the organism. Simple diffuse flashes of light have been used as stimuli in all VER-IQ studies with two exceptions which have used checkerboard patterns (Galbraith et al., 1970; Marcus, 1970). There is strong evidence that diffuse light is processed differently in the cortex than patterned light (Hubel and Wiesel, 1962; Perry and Childers, 1968). It seems possible then, that a VER evoked by patterned stimuli might be more reflective of differences in cortical processing related to intellectual ability, than would a VER evoked by diffuse stimulation. This rationale is readily subject to experimentation and testing.

The major purpose of this study, then, is to determine how the correlations between the VER and intellectual ability are affected by stimuli of greater complexity. It is hypothesized that VERs generated by patterned stimuli (checkerboard, word, and nonsense syllable) will yield higher correlations with IQ than the VER generated by diffuse stimuli.

It is, of course, impossible to quantify visual complexity. One can confidently say that a patterned stimulus is more complex than a diffuse stimulus, but beyond that a rank ordering of complexity is hypothetical. One could argue that a word is the most complex because of its symbolic verbal content and "meaningfulness." Yet, it could also be said that the nonsense syllable, as the most novel and unfamiliar stimulus, might initiate more sustained cognitive activity and attention. A case could also be made for the checkerboard, as it has the largest number of edges, has a verbal label, and may stimulate a variety of associations. The various stimuli cannot be ranked authoritatively for complexity then. However, it is postulated for the purposes of this discussion that the checkerboard is the least complex of the patterned stimuli since it is essentially non-verbal, is highly repetitive in content, and has a somewhat limited association value. The word is considered to be more complex, since it requires cortical processing as a verbal and "meaningful" information. The nonsense syllable will be considered most complex, as it is a novel verbal stimulus which might have a large number of associations attached to it because it lacks any well-defined meaning.

Another variable which has not been considered in the VER-IQ literature is the validity of the instrument used to measure intelligence. It is well-documented that socio-economic status (SES) is related to poor performance on IQ tests, poor school achievement, lack of motivation, and slow development of language skills (Terman and Merrill, 1927; McNemar, 1942; Jones, 1954; Bloom, 1964a,1964b;Kagan, 1970; Ginsburg, 1972). Conventional intelligence tests contain items which are educationally and culturally biased to the advantage of middle and upper SES groups, at the expense of the lower SES groups (Cattell and Cattell, 1959). In order to control for this bias, a test which is relatively free of contamination by the effects of school achievement will be administered in addition to a conventional intelligence test. It is hypothesized that VER-IQ correlations will be higher when intelligence is measured by this test than when it is measured by the conventional test.

METHOD

Subjects

Thirty-seven boys between the ages of ten and eleven, who attended P. K. Yonge Laboratory School, were chosen as subjects. This age group was chosen because the children were old enough to sit quietly and attend to the stimulus, yet young enough to avoid what unknown neurological effects puberty might have. The visual acuity of each boy was measured with a Snellen chart, and only those with an acuity of 20/25 or better in each eye were accepted for the study. In addition, Ss with a history of neurological dysfunction or visual defect were excluded. The IQs of the Ss, as measured by the short form of the Weschler Intelligence Scale for Children (WISC), ranged from 88 (dull normal) to 138 (very superior), with a mean of 119.

Psychometric testing

Two intelligence tests were administered to each S. One, a short form of the WISC, consisted of the following subtests: Information, Arithmetic, Vocabulary, Picture Arrangement, and Block Design. This is the pentad which correlates best with the Full Scale WISC, r = .92, when corrected for subtest reliability (Silverstein, 1970). Verbal and Performance scores for the WISC were calculated separately as well. In addition, the Culture Fair Intelligence Test was administered in a group to all Ss. This was chosen as a measure because it is considered to be relatively free from specific educational and social biases (Cattell, 1940; Cattell, Feingold, & Sarason, 1941), as well as a valid indicator of general ability (Cattell et al., 1941; Tilton, 1949; Geist, 1954; Marquant & Bailey, 1955).

VER recording procedure

Silver-silver chloride electrodes (Beckman) were used to record VERs monopolarly from the scalp, from positions C_3 and C_4 of the International 10-20 electrode system, with the reference electrode clipped to the ipsilateral ear. These locations have been used by a number of investigators in both monopolar and bipolar derivations (Ertl, 1968; Plum, 1968; Rhodes et al., 1969; Weinberg, 1969; Richlin et al., 1971).

Microdot cable was used for leads from the electrodes to the amplifiers, in order to minimize movement artifacts. Electrical activity from the scalp was amplified by Grass P-511 Amplifiers (Bandwidth 0.15-50 Hz) during stimulus presentation. The EEG signals were monitored visually on a Tektronix Type 564 oscilloscope. After amplification, the electrical activity was simultaneously routed to four channels of a Computer of Average Transits (CAT 400B) for on-line summation, and onto a seven channel FM magnetic tape recorder (Sanborn 7000) for subsequent analysis.

The stimuli were prepared on 2" x 2" slides and were projected onto a diffuse light screen by two Viewlex V-27 projectors which were custom-mounted on a common base. Stimulus duration was 500 msec. with an interstimulus interval of 1500 msec., determined by Gerbrandt electronic shutters controlled by a Grass 5-8 Stimulator. The long stimulus duration was used to avoid the "on" and "off" response mixtures obtained with short pulse or strobe stimulation. The stimuli subtended a visual angle of 6 ° on a side and were viewed under binocular conditions. The S was seated in a padded chair and stimuli appeared on the screen 6 ft. in front of the S. The luminance level of the stimuli was 8 ft. cdl. on a dark surround for all stimulus conditions, and was equated by a Variac variable transformer. Luminance was measured by a photometer (UDT 40A Opto-Meter), with the sensor at approximately the same distance from the screen as the S.

Each VER recording was the summation of responses to 60 stimulus repetitions; two such recordings were obtained for each of the four stimulus conditions. The four stimulus conditions used were:

1. Diffuse light flash
2. Checkerboard pattern
3. Word ("FOR")
4. Nonsense syllable("RFO")

(see Figure 1).

The specific word was chosen because it is a high frequency word (Kucera and Francis, 1967) which is classified at a primary reading level. The nonsense syllable is a recombination of the same three letters. In order to minimize the effects of habituation (response decrement occuring with repetitive

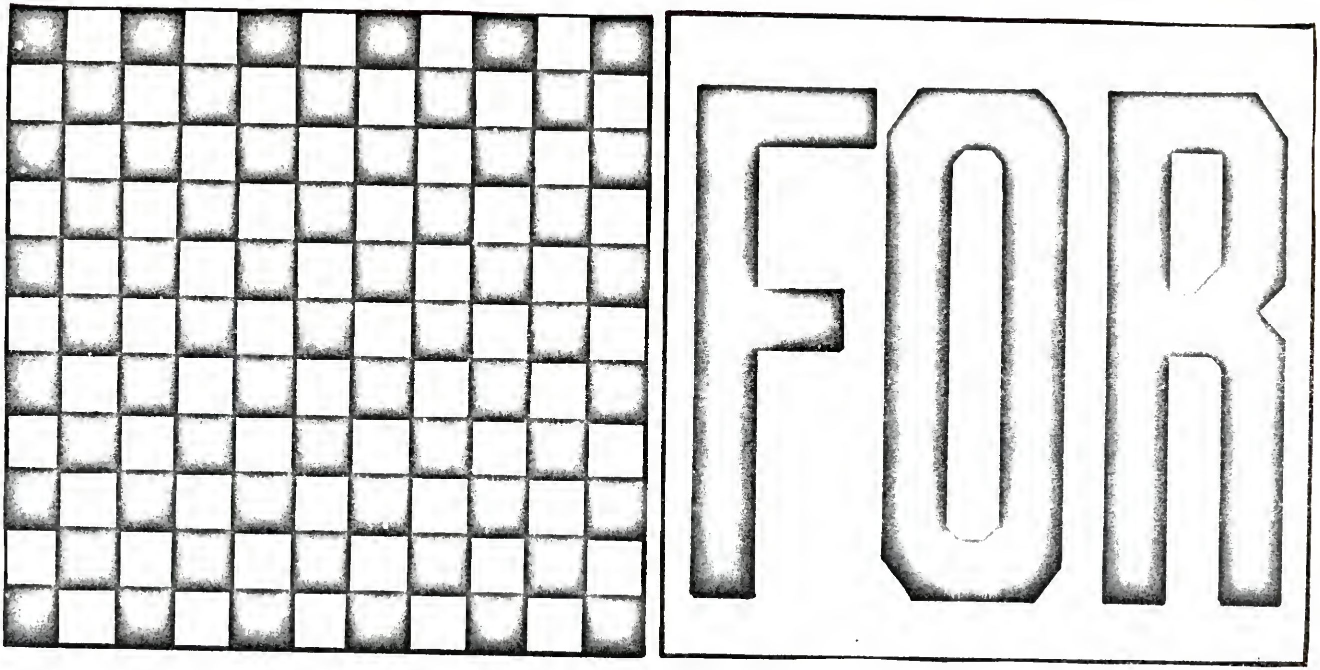


Figure 1. Examples of the stimuli used for the Check and Word conditions. Stimuli used for the Flash and Nonsense conditions were comparable.

stimulation), two stimuli were presented in random order during a single trial. An incremental film strip reader was used to program the random order of presentation. A binary signal was recorded on a channel of the tape to enable relay switching in the CAT to summate responses evoked by each stimulus separately. The Flash and Check were in two trials, and the Word and Nonsense in the other two. A trial consisted of 60 presentations of each stimulus, or a total of 120 presentations. Each trial took four minutes, and a brief (two minute) rest period was allowed after each trial. In addition, two control trials in which no light stimulation reached the eyes were performed to test for the intrusion of artifacts. The control trials consisted of 60 repetitions, and took two minutes. The order in which stimulus conditions and control trials were presented was randomized.

Experimental procedure

Upon arrival in the laboratory, the S was tested for visual acuity with a Snellen chart. The intelligence testing had been completed previously at the school. The S's head was measured for electrode placement, the sites cleaned with alcohol, and the electrodes placed on positions C_3 and C_4. The S was then seated in an electrically shielded, sound-dampened and light-proof room. He was instructed to sit quietly without moving his head, and to watch the flashing lights. The S was then fitted with earphones through which white noise was transmitted in order to prevent the sound of the shutters from evoking an auditory response. The lights inside the room were turned off, and the trials began approximately 2 min. later. The session lasted about 30 min.

Data analysis

Analog data tapes were played back following the experimental procedure and data obtained in analog form by a Varian F-50 Plotter. This yielded for each S two VERs for each condition, which were then superimposed and averaged by visual inspection. All subsequent analyses utilized this single averaged VER. Latency was measured in milliseconds from the beginning of the response to each peak. Amplitude was determined by measuring vertical distance in microvolts, with reference to the preceding peak. Latencies and amplitudes of the components were then correlated with the intellectual measures using the Pearson product-moment procedure. Only the later VER components (80-400 msec.) were correlated with the intelligence measures, since most investigators have found that correlations with intelligence occur within that range (Rhodes et al., 1969; Galbraith et al., 1970).

RESULTS

Latency and Amplitude

The data appear to best fit the waveshape described by Gastaut and Regis (1965), and the components were labelled IV, Va, Vb, Vc, and VI (see Figure 2). Only these five waves were analyzed for the purposes of this study, since these have been found to be most related to measures of intelligence. The components IV, Va, and VI were quite stable across Ss, and Vb and Vc less so. A sample of the VER data can be seen in Figure 3 .

There were a total of 66 significant correlations out of a possible 320. Correlations ranged from +.55 to -.72, with a mean of -.17. With a sample size of 37 Ss, correlations of .33 and above are significant at the .05 level; however, due to the absence of particular components in the VERs of some Ss, the actual sample size for statistical purposes numbered as low as 20, requiring a correlation of .42 for significance at the .05 level (see Table 1).

Some of the correlations are strikingly high, up to -.72, which are as high as those achieved by Chalke and Ertl (1965) and by Galbraith and his co-workers (1970). They are considerably higher than those achieved by several other studies (Plum, 1968; Shucard and Horn, 1972, 1973). These high correlations appear to be densely clustered around the three central components of the response, Va, Vb, and Vc, especially under

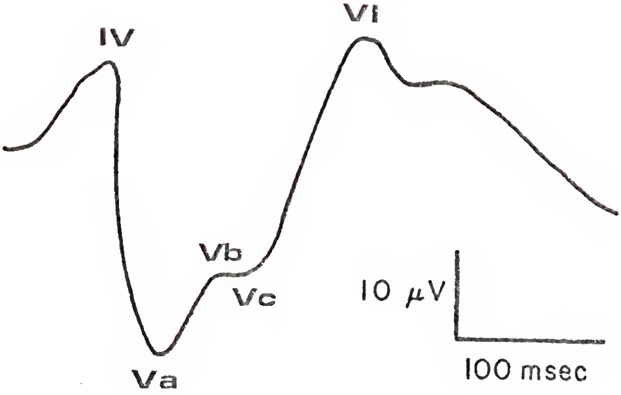


Figure 2. Representative VER with component disignations exemplified by Gastaut and Regis (1965), illustrating the components used for data analysis in this study.

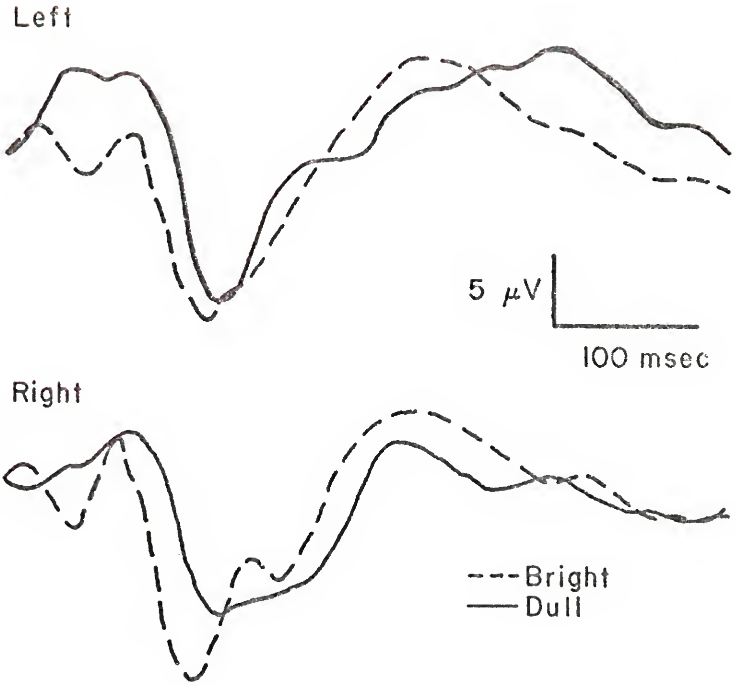


Figure3. Typical VERs recorded from a bright and dull subject.

TABLE 1

Significant correlations between VER measures and intelligence tests under four stimulus conditions

WISC - Wechsler Intelligence Scale for Children
VERB - WISC Verbal Score
PERF - WISC Performance Score
CFT - Culture Fair Test

			IV		Va		Vb		Vc		VI
			L	R	L	R	L	R	L	R	L	R
FLASH												
LATENCY	WISC		-.49*	-.57**	-.59**	-.72**	-.72**	-.57**	-.64**		-.33*
	VERB		-.43*	-.54**	-.54**	-.71**	-.59**	-.56**	-.56**		-.35*
	PERF			-.34*	-.38*		-.55**				
	CFT										
AMPLITUDE	WISC					-.61**		.43*			
	VERB					-.61**					
	PERF							.55*			.37*
	CFT					-.51**					
CHECK											
LATENCY	WISC				-.37*	-.62**	-.37*	-.53**	-.62**		
	VERB					-.69**	-.34*	-.71**	-.63**		
	PERF										
	CFT										
AMPLITUDE	WISC					-.66**	-.50**				.40*
	VERB	-.42*				-.67**	-.40*				
	PERF						-.38*				.40*
	CFT										
WORD											
LATENCY	WISC				-.36*	-.54**		-.42*			
	VERB					-.45*					
	PERF				-.39*						
	CFT				-.43*		-.39*				
AMPLITUDE	WISC				-.37*						
	VERB				-.43*						
	PERF										
	CFT										

TABLE 1 - continued

		IV		Va		Vb		Vc		VI	
		L	R	L	R	L	R	L	R	L	R
NONSENSE											
LATENCY	WISC			-.35*					-.58**		-.37*
	VERB								-.43*		
	PERF			-.47**					-.57**		
	CFT				-.36*					-.39*	
AMPLITUDE	WISC			-.40*	-.40*	-.42*					
	VERB			-.41*	-.46**						
	PERF										
	CFT										

* Statistically significant at the .05 level
** statistically significant at the .01 level

L - Left hemisphere
R - Right hemisphere

the Flash condition, but also with the Checkerboard. Correlations tend to be lower and more scattered with the Word and Nonsense conditions. The largest number of correlations and those of the greatest magnitude were associated with response latency, but some high correlations were also seen with response amplitude. These high correlations occur primarily with the short form WISC and the Verbal score.

With one exception, all the correlations between response latency and the intellectual measures were in the negative direction. Short latency was associated with higher intellectual abilities and long latency with less ability. The picture is more complex with regard to amplitude. With the early wave components (IV, Va, Vb) all correlations were negative, indicating that larger amplitudes were related to less ability, and smaller amplitudes with more ability. However, with the two late components (Vc, VI) the correlations were in a positive direction; larger amplitudes were associated with higher intelligence and smaller amplitudes with lower intelligence. The number of significant correlations was different for latency and amplitude measures. There were 43 correlations above the level of significance with the latency measure, as compared with 23 for the amplitude measure.

Measures of Intelligence

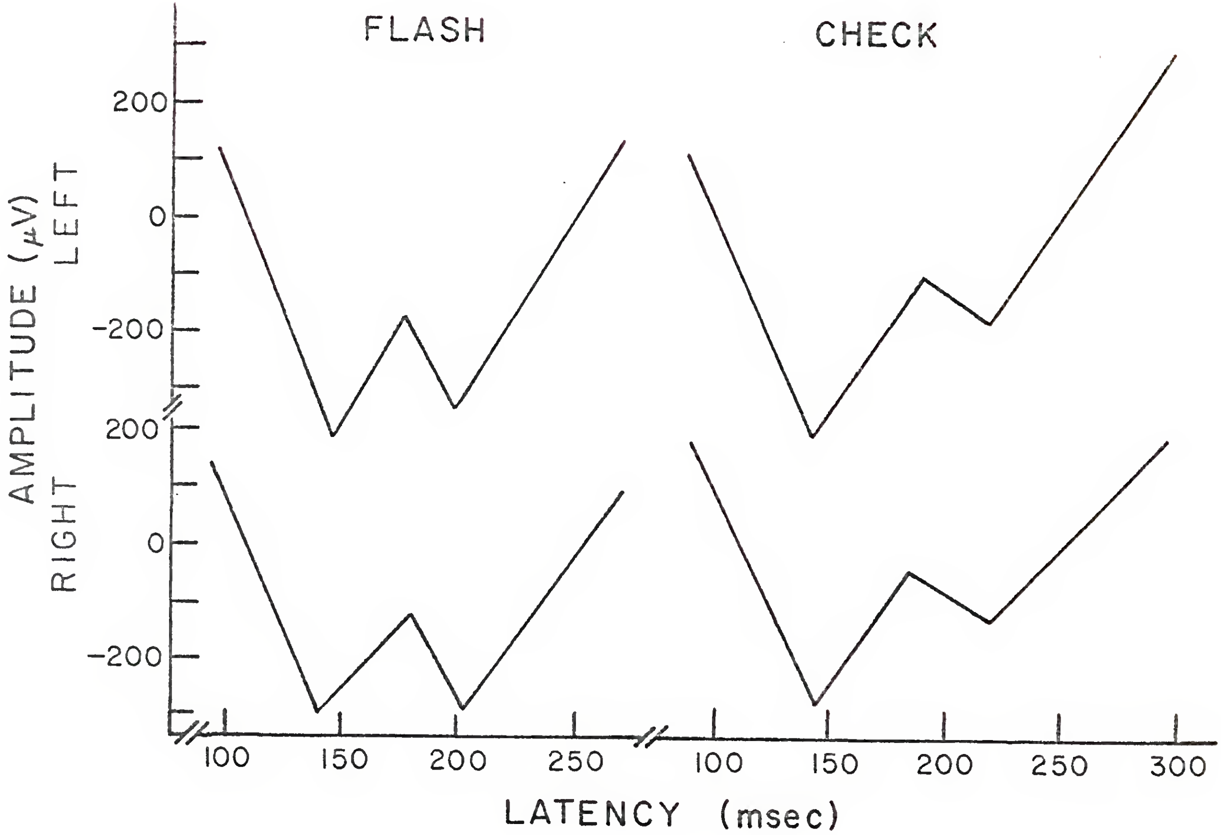
The number of significant correlations also varies with the measure of intelligence used. The VER measures were correlated with the short form WISC, its Verbal and Performance Scores, and with the Culture Fair Test. It was the short form

WISC which correlated best with the VER, accounting for 29 of the 66 significant correlations. The Verbal score also correlates well, with 23 correlations. Contrary to the hypothesis that the Culture Fair Test would correlate especially well with the VER, it accounted for only five of the significant correlations. The Performance score was little better with nine.

Stimulus Conditions

There were differences in the number of significant correlations occuring under the four different stimulus conditions. It was hypothesized that a more complex stimulus, such as a verbal one, would correlate better with the VER. Almost the opposite was seen to be true. It was the Flash condition which accounted for both the highest and the most correlations, 25, while the Word condition accounted for the least, nine. The Check and Nonsense conditions fell about midway between these with 17 and 15 correlations respectively.

Another way to look at differences between stimulus conditions is to average the latencies and amplitudes of all Ss to achieve one composite waveform for each hemisphere under each condition (see Figure 4). Although in general the waveshapes appear highly similar, several differences are notable. The composite VER elicited by the flash appears to be more like a "W" in shape than do the other waves; the negative peaks Va and Vc are more nearly on an even plane, while under all other conditions, Vc is considerably higher than Va. Latency differences between conditions are also apparent in the later components. The latencies of peaks Vb, Vc, and VI show a clear


FLASH
CHECK
AMPLITUDE (μV)
LEFT
RIGHT
200
0
-200
200
0
-200
100
150
200
250
100
150
200
250
300
LATENCY (msec)

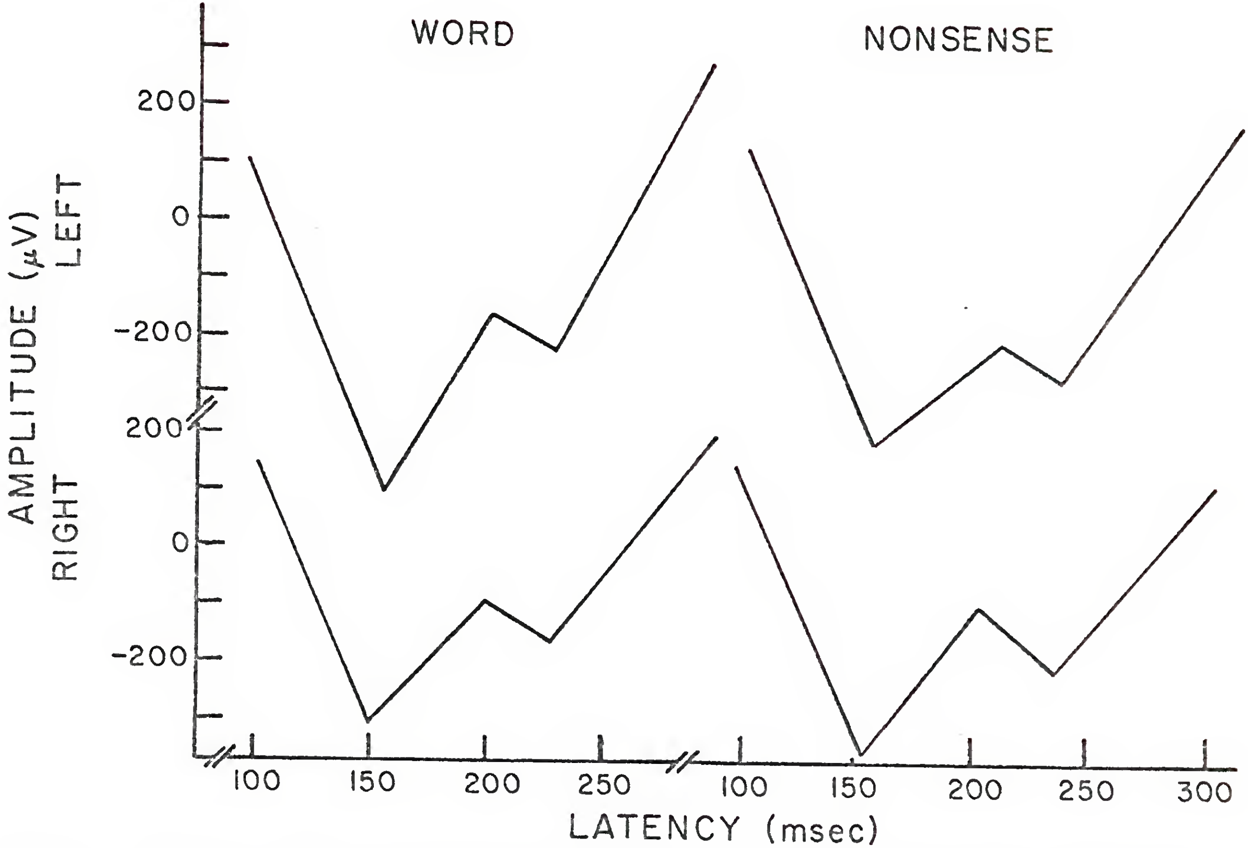


Figure 4. Schematic VER, based on mean latencies and amplitudes of each component for all subjects, under each of the four stimulus conditions.

trend toward increasing across conditions. That is, the component latencies are shortest under the Flash condition, longer under the Check, increase little or not at all with the Word, and are longest under the Nonsense condition.

Comparison of Bright and Dull Ss

It was thought that additional data could be gathered by a comparison of the brightest and dullest of the Ss within the sample. Twenty-two Ss were chosen by selecting the eleven boys with the highest short form WISC IQs, and the eleven with the lowest. The IQs of the bright group ranged from 125 to 138; those of the dull group from 88 to 106. These groups were significantly different for intelligence at the .01 level, on all four measures of intelligence. Means and standard deviations were calculated for each group, and t-tests performed between groups (see Table 2). As indicated by the previously mentioned correlations between VER measures and intelligence, the bright group has shorter latencies than the dull group under all stimulus conditions. The bright children tend to have smaller amplitudes in the earlier wave components than did the duller children, but larger amplitudes in the later components.

The difference between bright and dull groups is more clearly illustrated in Figure 5. Variations among stimulus conditions are apparent, as are variations between left and right hemispheres. For both Flash and Check conditions, the right hemisphere responses appear more flattened, with generally smaller amplitudes, than those of the left hemisphere. The

TABLE 2

Significant t-scores between the means of
VER measures of bright and dull groups

		IV		Va		Vb		Vc		IV	
		L	R	L	R	L	R	L	R	L	R
FLASH											
Laten-cy	$\overline{X}_B$	135	131			148	158	182	185		269
	$\overline{X}_D$	156	158			208	206	222	233		301
	t	2.76**	2.88**			3.50**	3.86**	2.82**	4.12**		2.18*
Ampli-tude	$\overline{X}_B$					62		269	142		
	$\overline{X}_D$					379		30	41		
	t					2.91**		3.06**	2.24*		
CHECK											
Laten-cy	$\overline{X}_B$				136	170	171	200	201		
	$\overline{X}_D$				152	221	195	246	237		
	t				2.19*	3.31**	2.11*	2.40*	2.35*		
Ampli-tude	$\overline{X}_B$					99	170			524	342
	$\overline{X}_D$					467	313			323	173
	t					3.55**	1.99*			1.91*	2.44*

TABLE 2 - continued

		IV		Va		Vb		Vc		IV	
		L	R	L	R	L	R	L	R	L	R
WORD											
Laten-cy	$\overline{X}_B$			150	141	184	185	214			
	$\overline{X}_D$			165	163	234	222	262			
	t			2.55*	3.72**	3.44**	2.93**	2.80**			
Ampli-tude	$\overline{X}_B$				355						
	$\overline{X}_D$				546						
	t				2.09*						
NONSENSE											
Laten-cy	$\overline{X}_B$					205		237	220		301
	$\overline{X}_D$					245		271	276		334
	t					2.64*		2.01*	4.13*		2.49*
Ampli-tude	$\overline{X}_B$	96		395	390	177					
	$\overline{X}_D$	201		643	624	469					
	t	1.91*		2.25*	2.41*	3.06**					

$\overline{X}_B$ - Mean of bright group

$\overline{X}_D$ - Mean of dull group

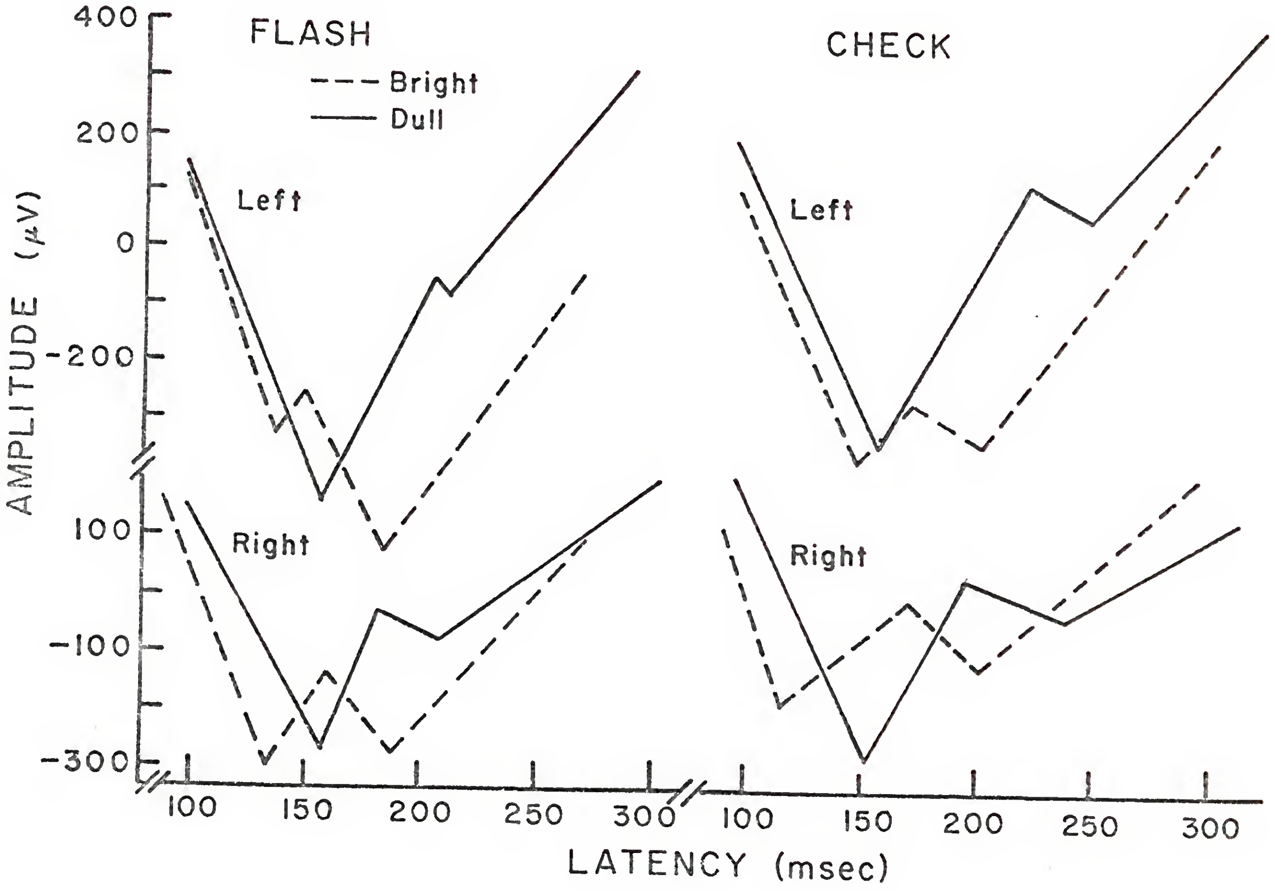
L - Left hemisphere

R - Right hemisphere

* Statistically significant at the .05 level

** Statistically significant at the .01 level

Note: Mean amplitude score x 10


FLASH
CHECK
Bright
Dull
Left
Right
Left
Right
AMPLITUDE (μV)
400
200
0
-200
100
-100
-300
100
150
200
250
300
100
150
200
250
300
LATENCY (msec)

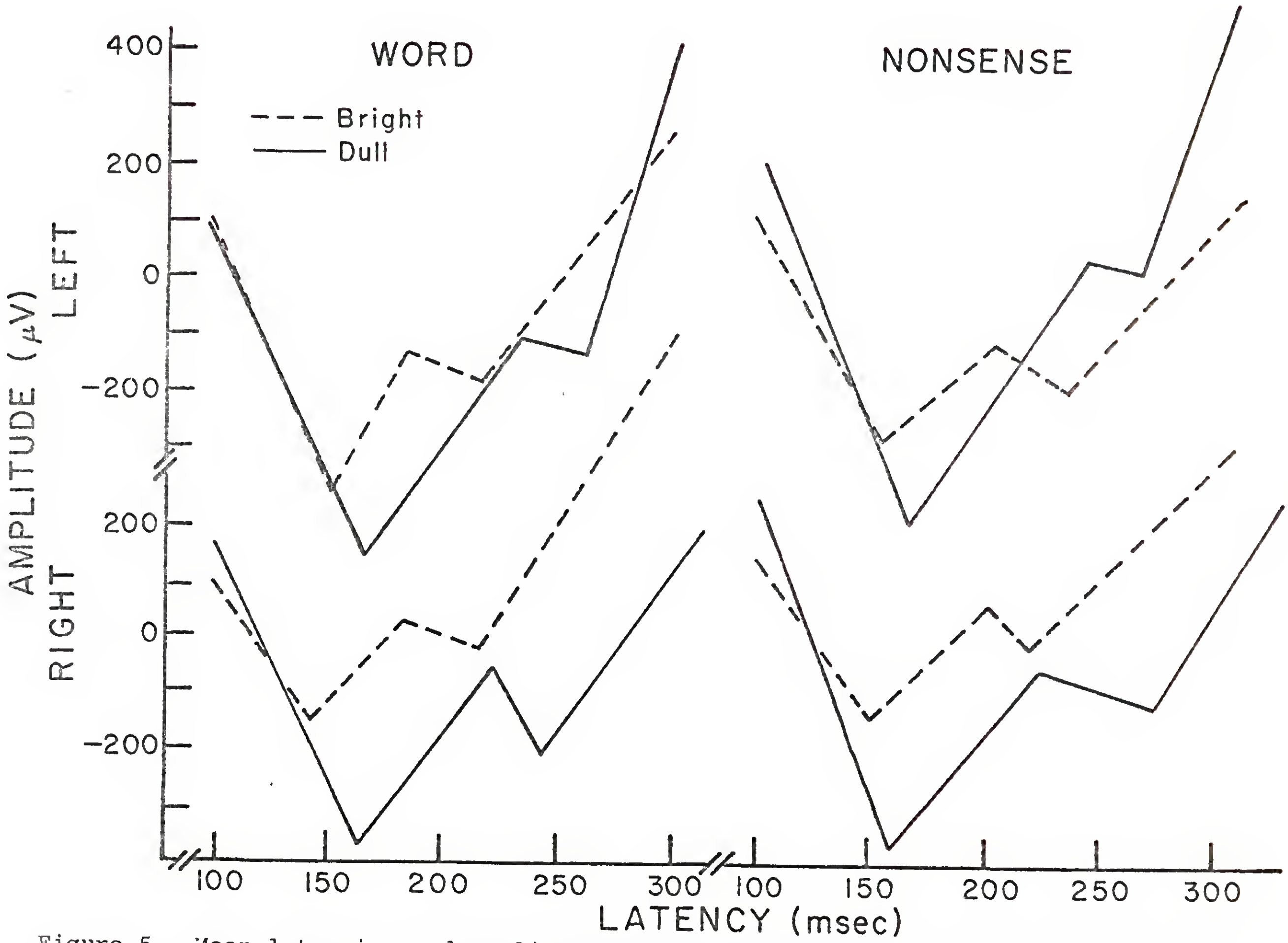


Figure 5. Mean latencies and amplitudes for 11 bright subjects compared with mean latencies and amplitudes for 11 dull subjects under each of the four stimulus conditions.

waveshapes of the responses from the right hemisphere are also quite similar in bright and dull groups. This is not true in the left hemisphere where the waveshapes for bright and dull groups appear markedly different, primarily due to the amplitude of the Vb component. With the Word and Nonsense conditions, it is also in the left hemisphere that waveshape differences between bright and dull groups are more apparent, again, primarily due to the amplitude of Vb. These hemispheric differences in waveshape cannot be accounted for by hemispheric asymmetry in either group, since t-tests performed between hemispheres for each group did not reach statistical significance. Rather they seem due to the differential amplitudes and to some extent, latencies, between groups. However, the number of *S*s in each group was small, and the standard deviations, especially of the amplitude measures large, so that hemispheric asymmetry cannot be completely discounted as a contributing factor.

DISCUSSION

The major hypothesis of this study, that more complex visual stimuli would correlate more highly with measures of intelligence than simpler stimuli was not upheld. Although there were clear differences between conditions, they were in the opposite direction from that predicted: it was the light flash which accounted for both the highest and the largest number of significant correlations with intelligence. Several explanations might account for this. It may be that response frequencies in the alpha range, 10-14 Hz, contribute heavily to the relationship between the VER and intelligence, and the correlations are best when this frequency is most in evidence, i.e., with diffuse stimuli, as in the Flash condition. In earlier studies, frequency analysis of the VERs elicited by diffuse stimulation revealed a predominance of frequencies in the alpha range (Ertl, 1971), while those frequencies were rarely seen when visually complex stimuli were used (Perry, Childers, and Falgout, 1972). Weinberg (1969) reports that the highest correlations with intelligence are associated with the frequencies of 12-14 Hz in VERs elicited by diffuse stimulation.

Another explanation of these differences might be based on the findings of several studies that VER differences related to intelligence tend to be obscured by increasing the Ss' level of attention or arousal (Plum, 1968; Shucard and Horn, 1972). Response amplitudes increase during conditions of high attention, while response latency decreases (Garcia-Austt, 1963; Haider, Spong, and Lindsley, 1964; Gross, Begleiter, Tobin, and Kissin, 1965). It will be remembered that most studies have found both shorter latencies and larger amplitudes were related to higher intelligence in children. It seems likely that brighter children are generally in higher states of arousal and attention than duller children, but the imposition of a simple task or arousal device stimulates relatively more arousal in duller Ss, thus obscuring the differences between them. Visually more complex stimuli, such as the check, word, and nonsense syllable, may be more arousing and attention-getting for the duller Ss than for the brighter, and thus tend to obscure differences between groups. A flash would have less arousing qualities, and therefore emphasize the intrinsic differences in arousal level between Ss. If component amplitudes, which are considered to reflect arousal, are ranked for size across conditions, there is a suggestion of a trend in this direction, although it is not of statistical significance. For dull Ss, the Nonsense condition elicits the highest amplitudes (suggesting higher arousal), and the Flash condition the lowest amplitudes. With the bright Ss, amplitudes are more nearly equal across conditions, indicating a more uniform level of arousal which seems less affected by extrinsic characteristics of the stimuli. This would lend support to the hypothesis that brighter children intrinsically maintain a higher level of arousal, and that duller children are less able to sustain attention when presented with simple stimuli, but are relatively more aroused by complex or meaningful stimuli.

It is interesting to note the differences in the composite waveforms across stimulus conditions. The waveshape evoked by the flash is distinct from those evoked by the patterned stimuli, appearing more like a "W". This is consistent with evidence that diffuse and patterned light are processed differently in the cortex. The increasing latencies of the composite VERs across conditions are also suggestive. The most complex stimulus, the nonsense syllable, shows the longest response latencies of the four stimulus conditions, suggesting it requires a relatively longer processing time in the cortex. The least complex stimulus, the flash,shows the shortest latencies, and might indicate the relatively quicker cortical processing of simple stimuli. The word and the check show more nearly equal latencies, midway between those of the flash and nonsense, and might indicate a similarity of cortical processing. It is possible that the check is being given an immediate verbal label by the S, and so is processed as a word, as well as a configuration.

The differences between the Word and Nonsense conditions, both in latencies and in the number of significant correlations are not of statistical significance. They are intriguing, however, because they are composed of identical letters, and more similarity might be expected if cortical processing was also identical. Although they vary in familiarity or novelty, it is debatable how novel any stimulus can be after 60 repetitions, so it would seem that meaningfulness is the principal dimension along which they vary. The word is defined by an assigned meaning, and in that sense is somewhat limited. The nonsense syllable has no particular meaning assigned to it, and is therefore more open to interpretation and varied associations. This less restricted quality may be more stimulating to the brighter Ss than the duller, and emphasize differences between them. There is evidence to suggest that meaningfulness of the stimuli is associated with enhancement of the VER (Symmes and Eisengart,1971), which might indicate increased arousal or attention. It is interesting to speculate on the possibility of a curvilinear relationship between the correlations with intelligence and the arousal value of the stimulus. The flash, as the simplest stimulus, is not very arousing for either group, and their intrinsically different levels of attention or arousal are made apparent. Word and check provide extrinsic arousal, which is relatively more arousing for the duller Ss, obscuring intersubject differences. The nonsense syllable also provides extrinsic stimulation, more so than the word or check, because of its lack of specificity, and makes differences between bright and dull Ss more general.

Another major hypothesis of this study was that the Culture Fair Test would prove a better instrument for assessing intelligence in relationship to the VER than would the WISC. However, just the reverse was shown to be the case. This is surprising since the Culture Fair Test emphasizes both speed and skill in the analysis and interpretation of visual information, abilities which one would expect to be important in the processing of visual stimuli in the VER. Rather, it is the short form WISC which is heavily loaded for verbal abilities, and the Verbal subtest of the WISC, which yields the majority of the significant correlations. These tests primarily measure verbal comprehension and skills related to school achievement.

There are generally thought to be three factors involved in intelligence: the ability to encode information, the ability to retain information over time, and the ability to retrieve information. Retrieval of stored inforamtion has two aspects: the recall of stored data in their original form, and the manipulation of relevant data to form new combinations. The WISC would seem to rely heavily on the more passive recall of learned information. The Culture Fair Test, in contrast, presents unfamiliar stimuli and demands a more active process of retrieval and recombination of relevant data in a new situation. This is consistent with the previous hypothesis that the VER correlates better with intelligence under less arousing conditions than under more arousing ones. The type of intelligence reflected in the VER then, would seem to be more in a passive, receptive mode than a more active, manipulative mode.

It is apparent from the results of this and other studies that the latency and amplitude of the VER have a significant relationship to intelligence, brighter *S*s tended to have shorter response latencies, duller *S*s tended to have longer latencies. It is thought that the shorter latencies reflect faster and more efficient neural processing of incoming stimuli, while longer latencies reflect slower and less efficient processing. However, a variation of one of Spitz's (1963) postulated of neural functioning in the mentally retarded might also apply. Spitz states that a relatively longer time is required to induce a temporary change in stimulated cortical cells in retardates than is required in normals. This implies that longer response latencies would be seen in the VERs of retardates as compared to normals. In a comparison of the VERs of normal and retarded *S*s, Galbraith and his coworkers (1970) have lent support to this hypothesis. It seems likely that this postulate would also apply more generally to the range of intellectual functioning in a normal population, i.e., in brighter individuals, cortical cells are more rapidly activated by stimulation than in dull individuals. The implication of shorter response latencies for brighter individuals was clearly borne out by this study.

The correlations between intelligence and response amplitude are confusing, however, and agree only in part with other work. The earlier wave components are negatively correlated with intelligence. Higher amplitude is associated with the duller *S*s, lower amplitudes with brighter *S*s.

Dustman and Beck (1969) reported that between the ages of 5 and 13, the amplitude of the BER response shows a marked decrease. The components which are reduced fall in the range of 70-225 msec.,which roughly corresponds to the latencies of components IV, Va, Vb. It seems possible that the brighter children are developmentally more mature than less bright children, and this difference is reflected in smaller component amplitudes characteristic of more advanced development of the central nervous system.

In summary, it seems clear that correlations can be found between the VER and measures of intelligence. These correlations appear to reflect both ongoing cognitive processes and underlying neural organization. However, it must be stressed that while VER-IQ correlations were significant, the possibility of assessing the intelligence of an individual is very limited due to the large variability of the response. Callaway (1973) makes the point that even perfect VER-IQ correlations would give a measure that was no better and very likely more expensive than a conventional test. Yet VER measures are less affected by specific learning and school performance, and may well cast new light on individual differences in cognitive functioning. It might prove especially useful in the early detection of subtle learning dysfunctions, such as dyslexia.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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